Automated Analysis of Natural Speech in Amyotrophic Lateral Sclerosis

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Background:
What do we know about speech in ALS?

• Impairments in
  • grammatical processing
  • action verb knowledge
  • discourse and social communication
  • Reading time (prolonged)

Speech is a multidimensional skill requiring the collaboration of multiple cognitive and motor domains. Our study assesses the interactions of motor and cognitive impairments on acoustic-prosodic aspects of speech in ALS and ALS-FTD.
Potential motor & cognitive effects on speech in ALS

**Cognitive**
- Behavioral (more common)
  - Social
  - Executive
- Linguistic
  - Agrammatism (more common)
  - Semantic
  - Audio-verbal

**Motor**
- Bulbar disease
- Reduced respiratory capacity
Study objectives

• Characterize acoustic-prosodic properties of speech in ALS spectrum
• Identify motor vs. cognitive effects on speech in ALS spectrum
• Implementation and validation of automated speech recognition in clinical settings
Hypothesis

• Acoustic features of speech in speakers with ALS and ALS-FTD can provide distinct markers that reflect motor and cognitive impairments.
Methods

• Digitized narrative speech samples - picture description task
• Automatic segmentation with a speech activity detector (SAD)
## Methods – patient groups

<table>
<thead>
<tr>
<th>Clinical &amp; Demographic characteristics - Mean (SD)</th>
<th>ALS</th>
<th>ALS-FTD</th>
<th>HC</th>
<th>bvFTD</th>
<th>naPPA</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>n</td>
<td>44</td>
<td>23</td>
<td>33</td>
<td>90</td>
<td>23</td>
<td></td>
</tr>
<tr>
<td>Sex = Male (%)</td>
<td>23  (52.3)</td>
<td>17 (73.9)</td>
<td>13 (39.4)</td>
<td>56 (62.2)</td>
<td>12 (52.2)</td>
<td>0.076</td>
</tr>
<tr>
<td>Age (y)</td>
<td>62.4 (10.4)</td>
<td>64.6 (8.8)</td>
<td>67.6 (6.2)</td>
<td>62.8 (8.7)</td>
<td>70.6 (9.2)</td>
<td>&lt;0.001</td>
</tr>
<tr>
<td>Education (y, n=210)</td>
<td>15.1 (2.8)</td>
<td>13.4 (2.1)</td>
<td>16.1 (2.5)</td>
<td>15.8 (2.8)</td>
<td>15.2 (3.0)</td>
<td>0.004</td>
</tr>
<tr>
<td>Symptom duration (y, n=179)</td>
<td>3.7 (2.6)</td>
<td>4.4 (3.6)</td>
<td>NA</td>
<td>4.4 (3.2)</td>
<td>3.4 (1.8)</td>
<td>0.408</td>
</tr>
<tr>
<td>Bulbar disease = yes (%)</td>
<td>16 (37.2)</td>
<td>8 (34.8)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
</tr>
<tr>
<td>%FVC (n=61)</td>
<td>78.5 (28.1)</td>
<td>63.7 (23.5)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.042</td>
</tr>
<tr>
<td>ALSFRS-R total score (0-48, n=61)</td>
<td>35.0 (7.5)</td>
<td>34.2 (7.1)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>0.709</td>
</tr>
<tr>
<td>ECAS total score (0-136, n=53)</td>
<td>115.1 (5.2)</td>
<td>84.7 (19.1)</td>
<td>NA</td>
<td>NA</td>
<td>NA</td>
<td>&lt;0.001</td>
</tr>
</tbody>
</table>

ALS - Amyotrophic lateral sclerosis; ALSFRS-R - ALS functional rating scale revised; ALS-FTD - ALS with frontotemporal dementia; bvFTD - behavioral variant FTD; ECAS - Edinburgh Cognitive Assessment Scale; %FVC - forced vital capacity (% of predicted by age); HC - healthy control; MMSE - minimental status examination; NA - not available; naPPA - nonfluent/agrammatic variant of Primary progressive aphasia; SD - standard deviation; y - years.
Methods – cont.

• Pitch tracking of continuous speech segments
• Duration measures for speech and silent pause segments
• Calculated acoustic measures: fundamental frequency (f0) range, mean speech and total speech durations, pause rate.
• Statistical analyses:
  • Group comparisons (controlling for age and education, adjusting for multiple comparisons)
  • Linear regression models:
    • acoustic measure ~ cognitive test score + motor function
    • cortical atrophy (MRI T1) ~ acoustic measure
Results

• f0 range is narrow in ALS spectrum disorders compared with normal speakers
Results - cont.

• Mean speech segment duration and total speech duration were shorter in ALS-FTD compared with normal and ALS speakers.

• Pause duration and rate were impaired in ALS-FTD compared with normal and ALS speakers.

• ALS-FTD speakers’ durational acoustic features most resemble bvFTD speakers’.
Results – Clinical correlates

- Impaired f0 range was related to bulbar disease (beta=-0.59, p=0.012)
- Speech duration (beta=0.38, p=0.006) was related to cognitive impairment independent of respiratory function
Results – Anatomical correlates

• Impaired f0 range (red) was associated with atrophy in primary motor cortex and left peri-Sylvian regions.

• Total speech duration (blue) was associated with atrophy in the IFG bilaterally.

• Lt. frontal operculum (magenta) linked to both f0 and speech
Conclusions

• Speech samples in ALS spectrum disorders can provide highly objective and reproducible markers of disease derived purely from the acoustic signal.

• Acoustic markers relate to prosodic elements of natural language such as fluency and intonation and reflect specific motor and cognitive impairments in ALS.
Resources

A full-length manuscript of this study was accepted for publication in Neurology.

Please refer questions and comments to the corresponding author:

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